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Significant and sustaining elevation of blood oxygen induced by Chinese cupping therapy as assessed by near-infrared spectroscopy

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Abstract: Cupping therapy has been used in traditional Chinese medicine for thousands of years to relieve muscle pain/tendency/fatigue and to cure or reduce symbols of other diseases. However, its therapeutic effect is sparsely interpreted in the language of modern physiology. To objectively evaluate its therapeutic effect, we focused on dry cupping treatment and utilized near-infrared spectroscopy (NIRS) to assess the concentration change in oxy-hemoglobin ([HbO_2]), deoxy-hemoglobin ([Hb]), and blood volume in the course of cupping therapy over 13 volunteers on the infraspinatus muscle, where is usually applied for shoulder pains. Both a prominent drop in [Hb] and a significant elevation in [HbO_2] in the tissue surrounding the cupping site were observed during both cupping and post-treatment, manifesting the enhancement of oxygen uptake. This resulting promotion indicates potential positive therapeutic effect of cupping therapy in hemodynamics for facilitating muscular functions.

OCIS codes: (170.6510) Spectroscopy, tissue diagnostics; (170.4580) Optical diagnostics for medicine.

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1. Introduction

As an important treatment method of traditional Chinese medicine (TCM), cupping therapy is broadly used in China to relieve muscle pain, tendency, and fatigue [1–5] caused by various reasons, such as long time working, high insensitive sporting. This method is also used to cure or reduce symbols of illnesses, e.g., fibromyalgia [1], carpal tunnel syndrome [6], herpes zoster [7] and postherpetic neuralgia [8], and caner pain [9]. In a general procedure of cupping treatment, the practitioner places a cup at the surface of treatment, with open side against the skin. Lower air pressure inside the cup is then produced by either a chemical method (e.g., burning up oxygen) or a mechanical method (e.g., air pumping). The lower air pressure will induce local stasis of blood in the area mantled by the cup. According to the theory of TCM, local stasis of blood could possibly motivate Qi (a mechanism closely relevant to the control of circulation) and blood in skin and muscle microcirculations mantled by the cup. Therapeutic aim in hemodynamic improvement is therefore achieved and can be enhanced when cupping is combined with other treatment approaches, such as medicine filling, bloodletting and acupuncture. The detailed mechanism of cupping therapy is illustrated in ref [10].

Though having attracted more and more interests from international populations such as Olympic athletes, cupping therapy still remains suspected of being a pseudoscience due to few objective evaluation of treatment efficiency by modern scientific criteria [11]. Previous studies mainly assessed therapeutic effects by surveying the changes in blood pressure [2], skin surface temperature [2], thermal effect [12], under skin blood flow [3], and scores of human feeling, such as pain intensity index, pain score, visual analog scale, fatigue severity scale and numeric rating scale [1, 5, 6, 13]. Although these metrics can quantify the alternations, the evaluations are conducted in subjective or macroscopic level, rather than

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metabolism level that directly correlates with physiological events in real time, especially for deep tissues.

Near-infrared spectroscopy (NIRS) offers a noninvasive, real time, portable, relatively inexpensive method for hemodynamic measurements and have been validated in many realms for metabolic quantifications since invented in the 1970s [14–16]. In the NIRS technique using continuous-wave (CW) light, photons at multiple wavelengths, typically ranging from 700 to 900 nm, penetrate through the biological tissues and the concentration changes of hemoglobin are quantified through the light intensity variation. Probing depth of NIRS can be centimeters sufficient for measurements of muscles in human subjects [17]. NIRS has been successfully utilized in a few therapeutic evaluation studies, such as massage therapy [18, 19], electrical stimulation [20, 21] and deep venous thrombosis [22].

In this study, we focused on assessment of single cupping therapy, without bloodletting (aka dry cupping) and any combination. We investigated the concentration changes in oxy-hemoglobin ([HbO_2]), deoxy-hemoglobin ([Hb]) and the derived change in blood volume ([tHb]) in the course of treatment on the infraspinatus muscles of human subjects. Statistically significant elevations in blood oxygen were observed, implying the efficiency of cupping therapy in enhancing hemodynamics.

2. Method

A custom-made CW NIRS oximeter (Fig. 1(a)) was engaged, which integrates a three-wavelength LED light source (735, 805, and 850 nm) and an optical detector. Light is injected into tissues via a probe containing an adhesive tip attached on the skin. The source-detector distance was set as 3.0 cm, allowing for larger than 1 cm penetration depth [23]. Δ[Hb] and Δ[HbO_2], i.e., the changes of [Hb] and [HbO_2], are then calculated out of the light intensity variations using the modified Beer-Lambert law [15, 24] and the derived $\Delta[tHb]$ is then calculated with $\Delta[tHb] = \Delta[\mathrm{Hb}] + \Delta[HbO_2]$. The sampling rate is 5 Hz. The details of the NIRS oximeter can be found at refs [22, 25].

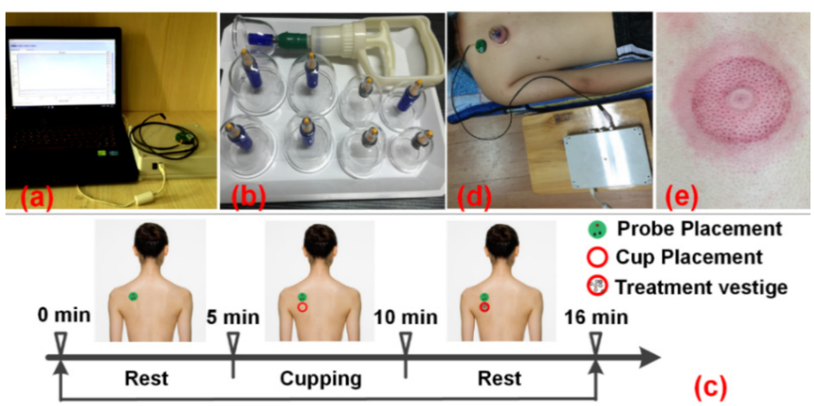

Fig. 1. The experiment device and protocol. (a) The NIRS system composed of a probe, a control module, and the software in a computer. (b) The cupping kit set. (c) Timeline of the measurement (d) A subject under treatment. (e) Treatment vestige.

A set of conventional cupping kit (Fig. 1(b)) was used for treatments. It includes a few cups and a mechanical exhauster which produces a scaled low air pressure circumstance inside the cups via sensing the air pressure on the tube wall.

Approved by the Human Subjects Institutional Review Board at University of Electronic Science and Technology of China, our experiment protocol (Fig. 1(c)) includes a 5-minute baseline measurement denoted by “baseline”, a 5-minute cupping treatment denoted by “cupping”, and a 6-minute recovery measurement denoted by “post-cupping”. Thirteen healthy volunteers, including 11 males and 2 females at an average age of 22.3 years old, participated in this study. None of the volunteers received any cupping or similar treatment within one year. Each subject laid prone. A cup was placed on his/her infraspinatus muscle. The probe of the NIRS oximeter was attached to the same muscle in 1 cm distance away from the cup placement (Fig. 1(d)). For each treatment, the pressure inside the cup was kept constant at 0.075 ± 0.005 MPa under the inspection of the practitioner. The room temperature was maintained at 25℃ and lights were remained off during the experiment. After treatment, the air valve was loosened and the air pressure restored as normal level as that in room circumstance. A telltale sign of cupping treatment, the red circle shown in Fig. 1(e), will appear after treatment and usually disappear in the next 3 days. The oxygenation data during the entire period of measurement was normalized to the baseline, i.e., the average data in the first 30 seconds. For statistical analyses, $p < 0.05$ was set as the significance criteria for all T-tests, one way ANOVA, and linear regression methods.

3. Results

We noticed that the data collected from 2 males were contaminated by strong motion artifacts caused by body posture adjustment. Their data were excluded and the rest 11 measurements were subsequently analyzed. Figure 2(a) shows the hemodynamic changes of a typical individual during cupping therapy. An obvious elevation in Δ [HbO_2] (5.53 μM at maximum and 4.91 μM on average) and a dramatic decline in Δ [Hb] (−24.00 μM at maximum and −19.56 μM on average) during the treatment were observed. The $\Delta[tHb]$ consequently has a mean decline of -14.65 μM possibly due to the suction effect of low air pressure. After the cupping therapy, Δ [HbO_2] decreased and Δ [Hb] increased as expected. In the post-cupping stage, the mean values of $\Delta[Hb]$, $\Delta[HbO_2]$ and $\Delta[tHb]$ were −9.11, 0.64, and −8.47 (μM) respectively, corresponding to 46.56%, 13.00% and 57.81% of the mean values in the cupping stage. All the mean values were calculated over the stable period as exampled in the green dash lines (about 5 mins for baseline and 4 mins for cupping and post-cupping). The variations were significant when compared with the baseline (N = 11, $p < 0.05$ in T-tests for all parameters.

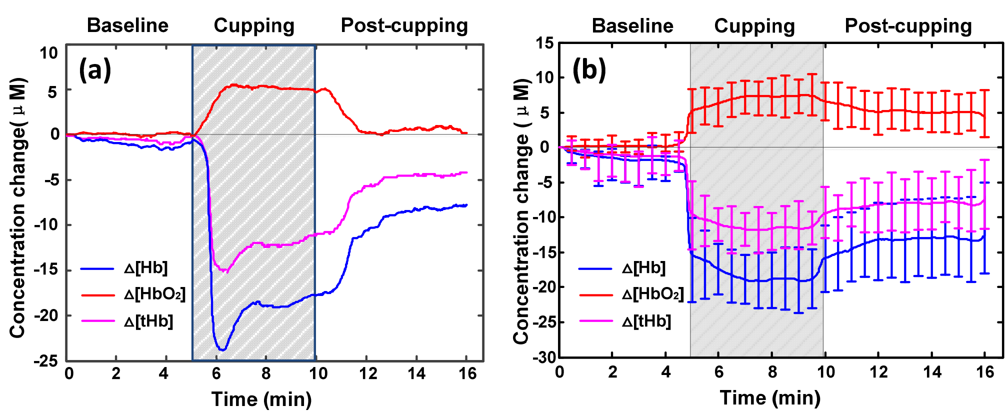

Fig. 2. Blood oxygen response in the course of cupping therapy. (a) Typical response from a representative individual subject during the experiment. (b) The mean response over 11 subjects. The bar represents the standard deviation.

The same trend was observed in the mean response of 11 subjects as shown in Fig. 2(b) where the data was down sampled to 0.5 Hz for clear display. Figure 3 displays the mean values of $\Delta[Hb]$, $\Delta[HbO_2]$ and $\Delta[tHb]$ respectively in the format of

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$mean \pm standard\ deviation$. During treatments, the Δ[Hb] decreased by $-19.43 \pm 3.83\,\mu M$ and Δ [HbO_2] increased by $7.73 \pm 2.56\,\mu M$, resulting in a $-11.70 \pm 2.71\,\mu M$ change in Δ[tHb]. The sustaining oxygenation changes were also observed after the air pressure was released. During the post-cupping stage, the mean values of Δ[Hb], $\Delta[HbO_2]$, and $\Delta[tHb]$ were -13.70 ± 4.98, 5.64 ± 2.68, and -8.06 ± 3.40 μM respectively All T-tests exhibit the significant alternations ($p < 0.05$, N = 11; Fig. 4) between each two stages in each variable of [Hb], $[HbO_2]$ and [tHb]. One-way ANOVA was performed to evaluate the difference among all stages for Δ[Hb], $\Delta[HbO_2]$ and Δ[tHb] respectively. Significances were found for all parameters ($p < 0.01$), specifically, F (2, 11) = 26.45 for $\Delta[HbO_2]$, F (2, 11) = 14.55 for Δ[Hb], and F (2, 11) = 17.49 for Δ[tHb].

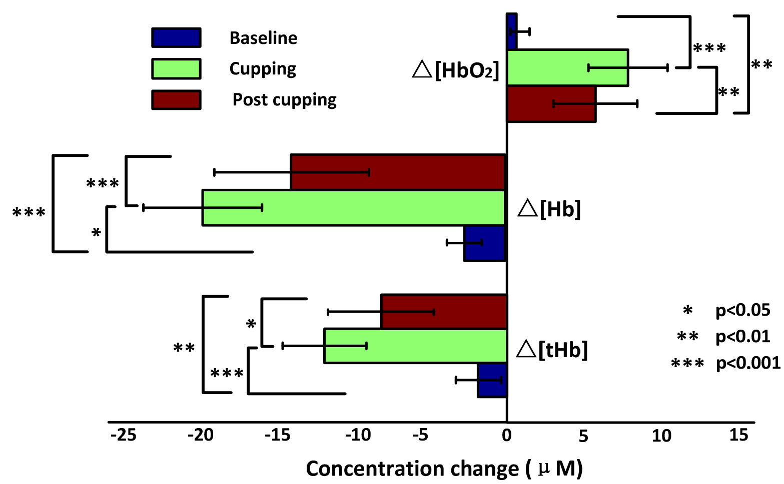

Fig. 3. The means and standard deviation bar of all measured hemodynamic parameters during the periods of baseline, cupping, and post-cupping. T-test results were shown by p-values.

4. Discussions and conclusion

In this study, we evaluated the efficiency of cupping therapy on the infraspinatus muscle. The inspected area is close to two acupunctural point SI9 and SI13 and is often applied during cupping and/or acupuncture therapy for shoulder pains [13]. Although this study was performed upon healthy subjects, the research outcomes may also have significant physiological implications for real clinical treatment such as shoulder pains.

During and post treatment, the [tHb] changes well reflected a physiological event that blood was promptly transferred from surrounding areas to the treatment area driven by the lower air pressure (i.e., concentration decline) and then a part of the blood flew back to the surrounding areas after the restoration of air pressure (i.e., partial recovery). However, cupping therapy doesn't only yield blood transportation, but also promote the oxygen level in the microcirculation as evidenced by the increase in [HbO_2] and the decrease in [Hb]. Blood oxygen saturation (StO_2), defined as $[HbO_2]/([Hb]+[HbO_2])$, consequently elevated since [HbO_2] proliferated ($\Delta[HbO_2] > 0$) and [Hb] + [HbO_2] dropped ($\Delta[Hb]+\Delta[HbO_2] < 0$, i.e, $\Delta[\mathrm{tHb}] < 0$). Enriched oxygen in tissue is always considered beneficial to the metabolism in muscle and consequent ameliorations in physiological functions by proliferating Adenosine Triphosphate (ATP) [26]. Similar elevations in [HbO_2] has been reported in other physical therapy studies such as muscle stimulation [20].

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The sustaining high oxygen level was spotted after treatment, as seen in Fig. 3. Limited by the experiment permission, we were unable to investigate the remaining duration of elevated $[HbO_2]$ here. To investigate the correlation between the intra-cupping and post-treatment alternations, we performed linear regression analysis and observed that significant correlation was only found for $[HbO_2]$ (Fig. 4(a), $p < 0.05$, $R = 0.87$; $y = 0.91x + 1.40$ where x and y are the $\Delta[HbO_2]$ in the cupping and post cupping stages respectively), but not for the other two (Fig. 4(b), $p = 0.09$ for $\Delta[\mathrm{tHb}]$; Fig. 4(c), $p = 0.08$ for $\Delta[\mathrm{Hb}]$). The slope of 0.91indicates that the post-cupping $\Delta[\mathrm{HbO_2}]$ went low when the low air pressure is removed. It also indicates that the sustaining high oxygen level in the post cupping was highly relevant to the cupping therapy and may be reasonably considered as a residual effect of the treatment. The restoration of blood volume and deoxy-hemoglobin, however, is little related to the alternations during the treatment, implying different therapeutic effects interpreted by different hemodynamic parameters.

We observe an outlier in the $\Delta[Hb]$, $\Delta[HbO_2]$ and $\Delta[tHb]$ above the line y = x in Fig. 4, which denotes that the oxygenation change in the post-treatment alteration was higher than the intra-cupping alternations. The only subject with these responses shows no distinctiveness in height, weight or health condition, but has almost no exercising time daily according to the personal information questionnaire. By contrast, the rest 10 subjects have an average exercising time of 40 minutes daily regardless of sport types. Although the links between exercising time and hemodynamics were not found, we assume that long time lack of exercise may have resulted in insensitivity in muscle functions of this subject and thus slower response to external motivations. We may recruit more subjects for further investigations.

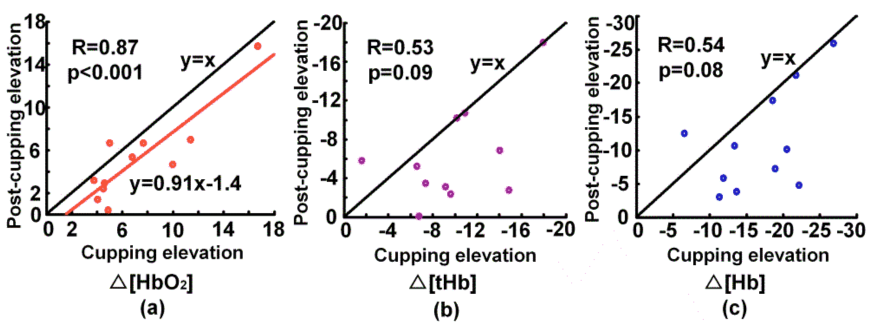

Fig. 4. Scatterplots of hemodynamics elevations during cupping (x axis) and post-cupping (y axis) periods respectively. Correlation results were reported with by R and p values. The regression line was drawn only when a significant correlation is found.

The treatment time of cupping varies among different clinical applications ranging from a few minutes to hours for one treatment. Accordingly, the physiological responses may also vary with treatment strategy. In this study, we used strong vacuuming and observed the physiological alternations in a 5 minute treatment, as suggested by the user instruction of the cupping kit. In the future, it may be necessary to trace the hemodynamic alternations in the treatments which requires long time but low vacuuming. Besides, simultaneous monitoring hemodynamics within and surrounding cupping region will help us to get more complete picture of the cupping therapeutic effect. Future research would also devote on the evaluation of cupping therapy in more metrics such as absolute quantification of blood oxygenation using frequency-domain NIRS technique [21] and deep tissue blood flow [24], multiple site measurement, and which tissue layer the cupping-therapeutic hemodynamic signal mainly coming from.

To conclude, we utilized CW-NIRS to assess the blood oxygenation change in the course of cupping therapy over 13 subjects. Results showed that the cupping therapy may help to

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reduce deoxy-hemoglobin and to obtain more oxy-hemoglobin, which enhances the local oxygen uptake and promotes the blood microcirculation and hemodynamic activity. The treatment induced an oxygen elevation in the local tissue to accelerate the possible repair or function of the local tissue, subsequently giving rise to positive therapeutic effects. This study paced a way to explore the mechanism of Chinese medicine in the view of biomedical science.

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